Measurements of the Top Quark Mass in the Lepton+Jets Channel at the Tevatron

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Abstract.
The top quark mass is a key parameter of the standard model. We present measurement of the top quark mass in the lepton+jets channel using data taken during Run II of the Fermilab Tevatron Collider in $p\bar{p}$ collisions at $\sqrt{s} = 1.96 TeV$. The lepton+jets final state is characterized by four or more jets, a high transverse momentum, isolated electron or muon and high missing transverse energy, resulting from the decay of one W boson into a charged lepton and a neutrino and the other W boson into a quark-antiquark pair.

Keywords: top mass, lepton+jets, template method, matrix element method
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MOTIVATION

Presently, a great deal of attention is paid to the top quark mass measurement. Such a mass measurement is extremely important for the measurement or a cross-check of the Higgs mass (provided it will be found in Lepton Hadron Collider). Although, the top mass measurement can help to identify properties of SuperSymmetry (again if it will be found). In the present proceeding a top mass measurement in lepton+jet channel with CDF and D0 detectors for RunII of Fermilab Tevatron collider is reported.

KINEMATICS

The branching ratio of $t \to Wb$ is close to 100%. For the $t\bar{t}$ pair process it means, that each top quark decays into a W boson and a b quark. W bosons can in turn decay hadronically into two jets or semileptonically into a charged lepton and a neutrino. We consider the final state, with one hadronic and one semileptonic decay. Thus the final state is characterized by two b jets, two light jets, an isolated charged electron or muon and a neutrino, that gives rise to a high missing transverse energy.

The only parameter, that can't be measured is longitudinal component of neutrino p_z. The three constraints come from the known masses of two W bosons and a test mass of top quark. Therefore, the 2C fit is carried out. However, there is an ambiguity of which jets come from which W bosons, therefore one should loop over all possible jets permutations. To reduce the number of permutations, b tagging is used.

Additional difficulty arises from the jet energy scale, which can influence the measured top mass. Therefore the best jet energy scale should be fit together with the top mass.

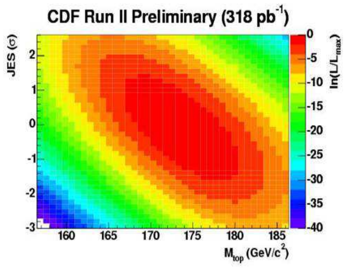

FIGURE 1. The best χ^2 fit for the template method

EXISTING TECHNIQUES FOR THE MASS RECONSTRUCTION

For the top mass reconstruction, two major methods exist: the template method and the matrix element method.

The Template method

In order to reconstruct the top mass, templates for each test top mass are created. Each template is a histogram for the reconstructed top mass with fixed generated test top mass. Then the fit is performed and the top mass, which gives the best χ^2 between the data and a template in an event by event basis, is found. The JES creates an additional complication, that's why the fit is performed simultaneously for the top mass and JES. Figure 1 gives the contour plot for the χ^2 (CDF). See [1] and [3] for the details.

The Matrix Element method

For a given sample the signal fraction is found as:

$$f_{top} = \frac{signal}{signal + background} \tag{1}$$

Then, the probability for an event to be consistent with some top test mass and JES is given by:

$$P_{evt}(x; m_{top}; JES) = f_{top} * P_{sgn}(x; m_{top}; JES) + (1 - f_{top}) * P_{bkg}(x; JES) \tag{2}$$

Here, x denotes all kinematic variables of the reconstructed lepton and jets, and P_{sgn},P_{bkg} are probabilities for the data to be consistent with signal and background respectively and depend on leading matrix element. Only events with exactly four identified jets are considered.

When using formula 2 all jets permutations are considered. To find the most probable (JES, m_{top}) combination, the likelihood function is calculated and minimized with respect to above quantities in event by event basis:

$$-lnL(m_{top}; JES) = -ln \prod P_{evt}(x_i; m_{top}; JES) \tag{3}$$

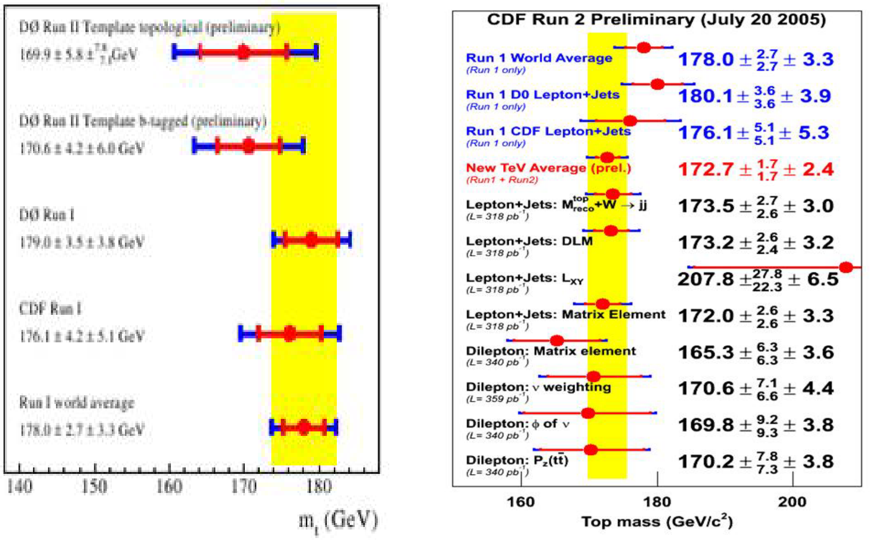

FIGURE 2. The mass measurement with different techniques for D0 and CDF respectively

See [2] and [4] for the details.

Calibration

To check the validity of the above mass reconstruction methods, the so called ensemble testing should be done. In order for that a set of ensembles are generated with some test top mass. Ideally the reconstructed and generated mass should coincide for each test mass and also estimated errors should make sense. In reality however some additional calibration should be applied based on the slope of reconstructed versus generated mass distribution.

RESULTS

The different top mass measurements are given in Figure 2. Both techniques are extensively used by D0 and CDF and give similar sensitivities. Systematics, especially JES becomes dominant with upcoming high luminosities, so the great challenge in 2006- is to understand and reduce it.

REFERENCES

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